FACTORS INFLUENCING THE LIKELIHOOD OF INITIATION OF INTERNAL EROSION INTO DRAINS				DATE: JULY 2012
Factor	**Influence on Likelihood / Relative to Reclamation Historical Base Rates (see notes)**			**Comments**
	Less Likely	**Neutral**	**More Likely**	
Material transport	No indications of sediment in seepage or catchment basis	No mechanism to monitor sediment transport (typically not possible in underdrains)	Sediment noted in pipe, catchment basins, or seepage flows	Evidence of material transport in seepage flow would indicate near certainty that erosion is occurring.
Toe Drains: Seepage Presence of seepage Seepage fluctuations	No seepage Long-term steady rate of seepage unrelated to reservoir level	Insignificant seepage; or within expected ranges Seepage fluctuates with reservoir, but at a predictable rate	Seepage significant Seepage is increasing over time at the same reservoir level; or seepage is episodic or surging.	Lack of seepage may indicate drain above ground water surface. Episodic seepage could be an indicator that an internal erosion pathway is repeatedly opening and closing.
Drain joints or cracks	No cracks or open joints noted	Very small cracks visible but not open, with no leakage.	Open joints or cracks. Much more likely for open joints or cracks with signs of erosion.	Width of joints or cracks should be compared to filter criteria (no erosion, excessive erosion, continuing erosion). This factor is related to both initiation and continuation because in some cases, a crack is the cause of initiation of erosion.
Pipe characteristics	Pipe consists of new materials (see Report DSO-09-01)	Clay or cement pipe laid with open joints Single wall HDPE pipe Corrugated metal pipe(CMP) and asbestos bonded CMP	Age may indicate degree or deterioration or corrosion.	Typical Reclamation dams are built with “sewer pipe laid with open joints” All pipe types are subject to deterioration.
Filter and drain envelope characteristics	Designed two-stage filter and drain envelope meeting current filter criteria Adequate width of filter and drain envelope	Single stage envelope. Minimal widths of filter and drain envelope	No sand or gravel envelope around drain	Evaluate filter and drain envelope for no erosion, some erosion, and continuing erosion criteria
Sinkholes or depressions on the embankment or foundation over the drain alignment	No observations of sinkholes or depressions.	Minor depressions over or near the drain alignment that developed slowly and do not change over time.	Observations of sinkholes or depressions over or near the drain alignment that appear suddenly.	Sinkholes or depressions that form directly over a drain are very likely related to the drain. The location of the sinkhole is a key factor in the seriousness of the concern. Inspection, exploration, and/or evaluation are needed to evaluate each site specific situation.
Structure Underdrains	Structure founded on non-erodible rock foundation.	Structure founded on well-graded compacted soil foundation or well-graded compacted fill. Structure founded on soft rock.	Structure founded on loose or poorly compacted soils. Much more likely if drain founded on fine-grained, non-plastic erodible or dispersive materials.	Surcharge pressures from outflows can cause materials surrounding pipe to be drawn into drains. Location of outfall may be a consideration.

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Factor	**Influence on Likelihood / Relative to Reclamation Historical Base Rates (see notes)**			**Comments**
	Less Likely	**Neutral**	**More Likely**	
Inspections	Inspections conducted over large percentage of pipe and no issues identified	Inspections only possible for short portion of pipe, but no issues identified Inspections not possible	Inspections possible and identify cracks, pipe failure, sags in pipe, plugging, root intrusion, deformation, etc.	Poor pipe condition does not automatically mean there is a high probability of an unfiltered exit. Plugging may improve conditions by raising tailwater and lowering gradient. Evaluation of inspection data should consider site specific conditions and potential failure modes. See [1] for more information on inspections of drains.
Voids below or adjacent to the pipe	Exploration programs (GPR, coring, etc.) confirm no voids present; no reason to believe voids might exist.	No exploration information. No reason to believe voids exist.	Exploration programs (GPR, coring, etc.) have confirmed the presence of voids under or adjacent to the conduit. Much more likely if voids are believed to be extensive and continuous. Judgment is required.	Exploration programs are not typically conducted unless there are signs of adverse performance or potentially high risks have been identified.
Location of toe drain		Drain located near toe of dam beneath impervious zones	Drain located more upstream than typical (beneath central portion of the dam).	The further upstream the drain is located, the shorter the seepage path and potentially higher gradients.

Notes on use of Table:

1. The factors on this table are specifically for potential failure modes related to internal erosion into a drain. Many other factors listed in the "Initiation of Internal Erosion through the Embankment" table are also relevant (e.g. erodibility, compaction of fill, construction factors, etc.) and should be considered when evaluating initiation of internal erosion into a drain.

2. Table is intended to provide guidance in addition to historical base rates of initiation of internal erosion. The neutral factors listed in the table would correspond to average base rates. Neutral factors do not imply a 50% probability. In general for a given Reclamation dam, there would be justification to select a probability of initiation of internal erosion higher than historical base rates if that dam was characterized by multiple "more likely" factors listed above; and conversely, there would be justification to select a probability of initiation of internal erosion lower than historical base rates if that dam was characterized by multiple "less likely" factors. Whether the estimated probability of initiation of internal erosion is higher, lower or at the historical base rate, the justification for the estimated probability must be documented. This table provides some guidance for that justification.

3. Some factors listed on the table apply to all internal erosion mechanisms (backward erosion piping, internal migration, scour, suffusion/suffosion) while some factors might only apply to one mechanism.

4. Some factors listed on the table are more critical to initiation of internal erosion into a drain than others. In general, more influential factors are listed towards the top of the table and less influential factors are listed towards the bottom.

5. Expert guidance is critical for interpreting observations at a dam and making judgments that relate performance of a specific dam to historical base rates of internal erosion.

References:

[1] Guidelines for Embankment Drain Inspections, Evaluation and Follow-Up Activities, Bureau of Reclamation, Denver, CO, July 2005.

[2] Drainage for Dams and Associated Structures, Bureau of Reclamation, Denver, CO, 2004.

[3] Draft Risk Analysis Methodology Appendix E (2000), Estimating Risk of Internal Erosion and Material Transport Failure Modes for Embankment Dams, version 2.4, Bureau of Reclamation, Technical Service Center, Denver, CO. August 18, 2000. (This document was never finalized; it was superseded in 2008 by Dam Safety Risk Analysis Best Practices Training Manual, Chapter 24.)

[4] Fell, R., C.F. Wan, and M. Foster (2004), "Progress Report on Methods for Estimating the Probability of Failure of Embankment Dams by Internal Erosion and Piping," University of New South Wales, Sydney, Australia. UNICIV Report 428. 2004.